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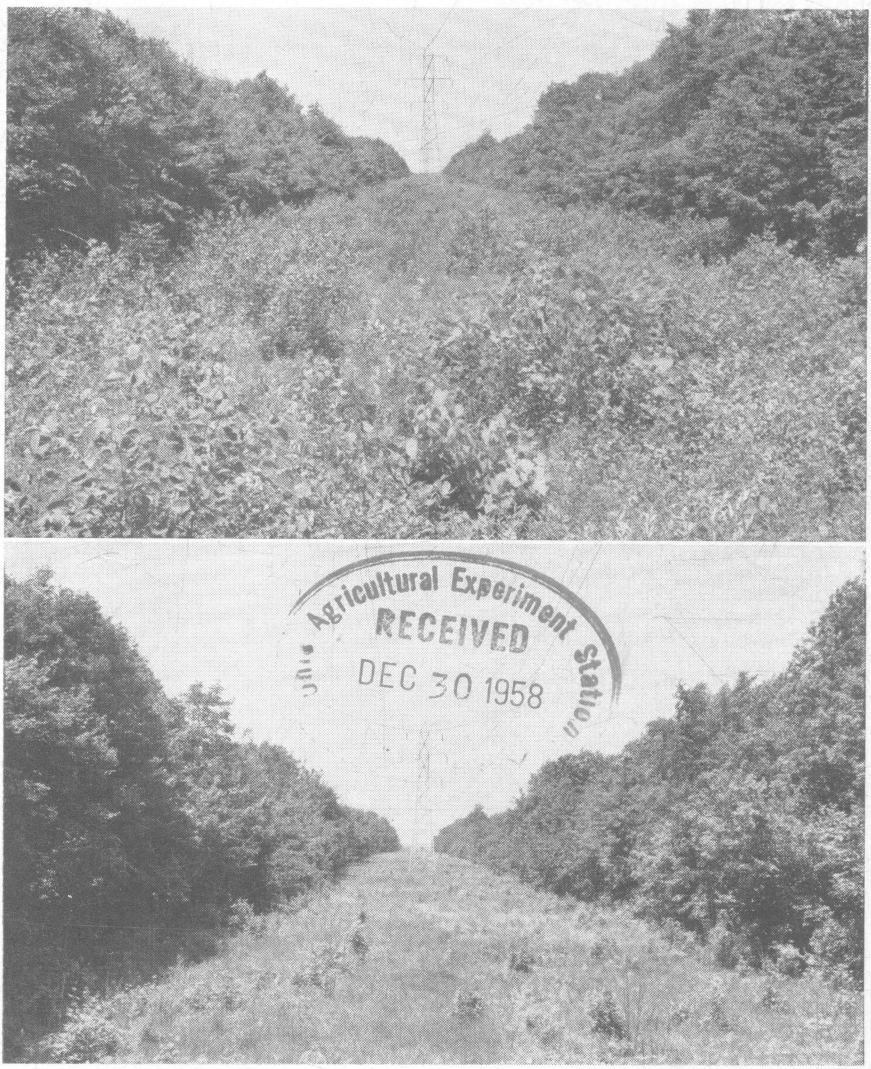
Chemical Control Of Woody Plants



Agricultural Extension Service
The Ohio State University

Our Cover

The top photo shows a utility right of way in 1954, just before it was sprayed with "brush-killer." The brush not killed was sprayed again in 1955. Bottom photo shows the scene in June, 1957.

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Chemical Control Of Woody Plants

With Special Empasis on Roadside and Utility Rights of Way

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The control of woody plants—brush, trees, sprouts, and vines—in areas where they are not wanted is a never ending job in a humid climate such as Ohio's. Sooner or later, trees and brush take over any untended area. Controlling such unwanted growth in unplowed or unplowable areas meant continuous hard labor until the advent of chemical controls.

Chemical vegetation control in its present form dates from the announcement of 2,4-D as an herbicide in 1945. It is true that some inorganic soil sterilants have been used to kill weeds since the late 1890's, but the new materials are so different and so much more widely used as to constitute a new era.

The abbreviation 2,4-D is for 2,4-dichlorophenoxyacetic acid, a name which tells the organic chemist exactly what the compound is, but is much too long for ordinary daily use, so "2,4-D" has been adopted as a common name. This is one of a series of such compounds, many of which have considerable and vital effects on plant life.

These products have the property of affecting plants at extremely low concentrations, as low as one part in a million or even one part in 10 million. They affect form and development of plants and are similar in many ways to the compounds which in animal physiology are called "hormones." For this reason these and other similar compounds which may be translocated (moved within the plant from the point of application) and affect plants in small quantities are frequently referred to as "hormone" herbicides. The term is in some respects not strictly correct, but for the sake of a short name it will be so used in this bulletin. They are contrasted to "contact" herbicides, whose effect is largely or entirely limited to the area to which they are applied, but there is no sharp line between them.

Chemical vegetation control with these hormone herbicides has proven effective and economical. It has received wide acceptance by

farmers, highway maintenance departments, utilities and others who must control the growth of brush, weeds and other undesired plants. It has reduced costs and saved untold hours of back-breaking labor. This bulletin is intended to give the techniques of chemical weed control presently available and discuss some of the problems raised in using these methods.

Our Chemical Tools

Compounds Related To 2,4-D

2,4-D. This herbicide is in many ways an ideal weed killer. It is effective in small doses on many plants, highly selective, non-toxic to man*, livestock or wildlife, non-corrosive to equipment, inexpensive, and easy to apply. In this climate, 2,4-D will not accumulate in the soil or affect it unfavorably. The heaviest doses are decomposed in the soil in 15 to 60 days. In dry soils and climates it may last all season or longer, but not here. It has no unfavorable effect on soil bacteria or other microorganisms. Farm and game animals (including fish), insects and man are unaffected by 2,4-D except in doses far above those received through any herbicide use.

2,4,5-T. There are many other compounds similar to 2,4-D, with similar general properties as just described and similar in control of vegetation. The most important of these is 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). To the chemist, it differs from 2,4-D only in having three chlorine atoms in its molecule instead of two, hence *tri-* instead of *di-*chlorophenoxyacetic acid. This compound is much more effective than 2,4-D on many woody plants and so is of major importance in woody plant control. On the other hand it is less effective than 2,4-D on some plants and has about the same effect as 2,4-D on many other plants. These two compounds, 2,4-D and 2,4,5-T, are today the most important in brush control and are often still further abbreviated to D and T. They are frequently sold and used in mixtures of the two, which are often called "brush killers."

If T sold at the same price as D, T would be the only product used for woody plant control in this area, since there are no important woody plants more sensitive to D than to T, and many which are controlled by T and not by D. However, T costs about twice as much per pound of acid as D, and with many plants more plants per dollar can be killed with the brush killer mixtures. At present, there are often not sufficient satisfactory data to permit making an accurate estimate of whether D, D and T, or T will be most economical for a specific job.

*There have been a few reports of persons who were allergic to 2,4-D This is important for these individuals, but the author knows personally more persons who are poisoned by eggs than the number of reports he has had of cases of allergy to this herbicide.

Under these circumstances the largest use is still of D and T "brush killers," but an increasing number of careful operators are using straight T on mixed brush. Where both herbaceous weeds and brush are to be controlled, as with average highway maintenance spraying, there is a large place for D and T, and D alone.

Silvex (2-(2,4,5-trichlorophenoxy)propionic acid), a hormone related to 2,4,5-T, has recently been introduced as a brush killer, to be used like 2,4,5-T as a foliage spray, but not as a basal spray. It is more effective on species of ash than either D or T. In a large-scale test in Pennsylvania, it was slightly but not significantly superior to 2,4,5-T on mixed brush, largely oaks and red maple. Several other related compounds are under test.

How do 2,4-D and related compounds kill plants? When absorbed by plants, these compounds have widely varying effects. With sufficient doses, some plants are killed almost at once after application. In other plants and other dosages they stimulate any tissue that is growing at the time to abnormal growth. They often stimulate respiration, and so cause exhaustion of reserve food materials in stems, roots, or elsewhere. Essentially, they disorganize the biochemical processes within the cells of plants so that they do not proceed, or proceed abnormally, but each kind of cell in each plant responds in its own almost unique way. In woody plants the most common effect from sufficient doses is death of the cells, but stunting and abnormal growth are also common effects.

Formulations of 2,4-D, 2,4,5-T, and similar compounds. These herbicides themselves are organic acids which are not soluble in water or oil and so cannot be used generally for weed-killing in their uncombined form. They must be compounded for use. These compounds and their formulations will, in turn, contain different proportions of 2,4-D or 2,4,5-T acid. Since the acids are the part of the compounds which kill the brush, all rates of application should be stated in terms of the amount of 2,4-D or 2,4,5-T acid present, that is, as the "acid equivalent." Recommended rates of use always refer to the acid equivalent. Liquid formulations state on the label the number of pounds of 2,4-D or 2,4,5-T acid equivalent present in one gallon of solution, so that making up solutions is fairly simple. There are two general types of formulations of these herbicides on the market:

1. Liquids that mix with water in any proportion, making clear solutions. These are water solutions of certain organic salts of 2,4-D, commonly referred to as amine salts or "amine" forms of 2,4-D.
2. Liquids that make milky mixtures (emulsions) with water. These contain esters of the acids, dissolved in miscible oils. Because they are oil solutions, which wet the plant and permit the herbicides to

penetrate, the ester forms are most effective on hard-to-kill plants, under dry conditions, and under unfavorable conditions generally. Rain, even immediately after application, does not materially affect applications of ester formulations. Esters are the most common forms of 2,4-D and 2,4,5-T used for woody plant control.

The esters first used were the alkyl esters (methyl, ethyl, butyl, isopropyl, pentyl and amyl). Recently much more complex long chain esters have been introduced as "low-volatile" esters. These actually are less volatile than the other esters, but another important reason for using the long chain or "low volatile" esters is their herbicidal activity. They are the most active compounds of 2,4-D and 2,4,5-T so far produced and are particularly valuable against woody plants.

Risks in using 2,4-D and 2,4,5-T. One must never forget, when using 2,4-D and 2,4,5-T, that he is using extremely potent materials. Damage to sensitive crops from careless application of 2,4-D has led to severe restriction of its use in some states. Use no more than necessary, and use every precaution to prevent drift and misapplication.

Drift and volatility. Drift and volatility are frequently confused. They are somewhat similar in result but distinct in origin. "Drift" refers to the down-wind drifting of droplets of spray at the time of application. If applied as a "fog" such droplets can easily drift a half mile or even more. "Volatility" refers to the evaporation of the herbicides after application, and moving with the wind in vapor form.

Drift. Any hormone chemical may give difficulty from drift, and much of the difficulty from these chemicals is due to drift. There may also be some injury from drift of contact herbicides, such as Ammate (which is not volatile). This will not be as serious as that from the hormone types, because only those parts of the plant which are directly wetted by the drifting droplets will be affected by a contact herbicide, and they will cover only a fraction of the plant.

Precautions to avoid drift include:

1. Use as low pressures as feasible. With any given nozzle, high pressures will produce smaller droplets than low pressures, and the distance of drift is largely determined by the size of the droplets.
2. Keep spray nozzles pointed down as much as possible, and always along the right of way, not across it.
3. Ester formulations are a greater drift risk than the amine salt formulations.

Drift, then, must always be guarded against as a hazard in applying the hormone chemicals, in particular, and all chemicals in general. Extreme care, using trained operators, low pressures, and nozzles producing

as large droplets as are feasible for the particular job being done, should be taken in all brush control spraying.

Volatility. No formulation of D or T is sufficiently volatile for the volatility to be measured by ordinary physical methods; nevertheless, sufficient vapor may arise from short-chain ester formulations to cause injury at a distance. Such widely used esters as the methyl, ethyl, propyl, isopropyl, butyl, pentyl and amyl esters can volatilize enough to injure near-by sensitive plants. This has been demonstrated by putting a few drops of these formulations on filter paper in a closed container with a sensitive plant, or by drawing air over a vessel of such formulations and then over a sensitive plant. In both instances the plants have been severely injured. A "low-volatile" ester is one which does not damage sensitive plants under these conditions. The use of "low-volatile" esters greatly reduces the volatility hazard.

Use of amine salt formulations of D and T to avoid injury to sensitive adjacent plants. Even with low-volatile esters, sensitive adjacent plants have frequently been injured, leading to ill feeling and damage suits. Several large operators have begun to use amine formulations for brush spraying and report greatly reduced complaints of injury with equally effective control. This is not yet general, but worthy of trial if complaints of injury are numerous.

Other Herbicides

Ammonium sulfamate is, next to the D and T compounds, the most important compound used in brush control. It is on the market under the trade name of Ammate-X. Ammate is a non-selective plant killer. It is not harmful to human beings, domestic animals or wildlife and, like the D and T sprays, will not sterilize the soil.

Ammate is non-volatile and can be used with comparative safety on brush adjacent to crops susceptible to the drift and vapors from the hormone compounds — provided the same common sense precautions are used that apply to any other spray. Compared with the D and T brush killers, Ammate has several disadvantages:

1. Initial cost of application is higher.
2. It is corrosive to spray equipment.
3. Much more herbicide is required per gallon of spray. This makes it more expensive and harder to handle.
4. It kills nearly all vegetation, especially grasses, leaving the soil more or less bare. This causes a "desert-like" appearance after application and may expose the soil to erosion.
5. It is not effective as a bark or basal spray.

Its great advantages are its freedom from damage through drift and volatility, and its effectiveness on ash and many oaks.

Arsenic. Arsenic compounds, particularly sodium arsenite, have been used for plant control for over 50 years. Sodium arsenite is an effective foliage spray but because of its deadly poisonous nature should not ordinarily be so used. The foliage spray does not usually kill the roots. It is very effective applied in frills or cut surfaces, but, here again, it must not be used where animals have access to the treated trees. A recently developed method of applying sodium arsenite under the bark on blotting paper tabs, may have limited application for tree killing in Ohio, especially for eliminating weed trees in forests. Concentrated sodium arsenite solution is absorbed on 2 x ½ inch strips of blotting paper and inserted under the bark of the tree to be killed, using a simple curved spud a half inch wide to make the pocket and to push in the tab.

New Materials

While brush control is now largely carried out by applications of 2,4-D, 2,4,5-T, and Ammate, many new materials are under test. Some of them will probably be recommended commercially before long. The following notes are not intended as recommendations, but are suggestions of things that may be in the future.

Monuron. Monuron, originally introduced as CMU and now sold under the trademark Telvar W, may have considerable value in woody plant control. It is already a standard material for soil sterilization. It is notorious for its serious effects on trees whenever applied near tree roots. It has been applied in strips near the bases of weedy species of oak and injected into the soil adjacent to tree roots, with considerable success. The high price of the product is a present difficulty. It should not be applied as a wettable powder on the soil surface if there are valuable plants in the line of surface drainage. It has killed plants after being washed a quarter of a mile from the point of application. Large all-over doses will prevent all growth and open the soil to erosion.

TCB (Trichlorobenzoic acids, especially 2,3,6-trichlorobenzoic acid.) These compounds have given excellent experimental results on some woody plants. They are not yet on the market, but it is possible that they will be valuable in the future. They are especially active on conifers.

ATA (3-Amino-1,2,4-triazole.) This material, sold under the trademarks Amino Triazole Weedkiller and Weedazol, is unusually effective on poison ivy and should be used on small areas of poison ivy near gar-

dens or in towns, where the hormone chemicals are inadmissible. It may prove desirable for use on some other hard-to-kill woody species, but its highly selective action makes it unlikely that it will be used for general brush spraying.

What Brush Can Be Chemically Controlled?

There have been many requests for a list of species with their reaction to various sprays. Such a list is desirable, and ultimately we will have it. Several such lists have been compiled by the various weed control conferences, and more lists could be compiled from their reports of experimental work. Any such list at the present time is much less than satisfactory for several reasons:

1. It must be based on grossly insufficient data. Many lists and research reports identify the plant treated only to the genus, and yet all experience shows that the species and even the variety of plant involved makes an important difference in its reaction to herbicides. (The Winesap group of apples, e.g., is well known to be much more easily injured by 2,4-D than most other varieties.)
2. Plants also differ in susceptibility at different stages of growth, under different conditions of growth, and at different seasons of the year. No summary list can recognize all of these factors, nor are the data available to recognize them intelligently. These variables add greatly to the confusion of any published table, since many plants have been listed as susceptible, intermediate, and resistant to a given herbicide in different lists at different times.
3. Practically anywhere east of the Mississippi river it is unusual for the woody plants along a right of way or highway to be of only one species. Where they are, it is, of course, profitable to tailor the herbicide application to that species. Usually there are many species in any given eradication job. Furthermore, no eradication job, whether of one species or several, is ever completed at one application, so that in practice we treat mixed brush with the formulation which seems best adapted to the conditions and the majority of species present, and then treat again according to what is left. This approach will be necessary in most instances, regardless of the information provided in lists of susceptibility.

In this bulletin, therefore, we have given up any attempt to indicate in tabular form the reaction of all the many woody species which we

may, in one situation or another in Ohio, wish to treat chemically. For the benefit of those with little experience in this field, some general classifications may be given.

The needle evergreens (pines, spruces, firs, etc.), more or less without exception, are not killed by the foliage sprays described in this bulletin. Ash (*Fraxinus* sp.) is universally reported as the most resistant broadleaf genus, though there are considerable differences between species. The maples are probably next in difficulty of killing, with red maple causing the most trouble. Oaks, basswood, hickories, and hackberry, perhaps in that order, are next most frequently referred to as difficult to kill, again with considerable differences between species. Persimmon and dogwood are difficult to kill, as are several other less common trees. Osage orange and the briars, blackberry, dewberry, etc., (*Rubus* sp.) are readily killed by 2,4,5-T, but are almost immune to 2,4-D. Of the many woody plants killed with essentially equal ease by D or T, only the most common species of willow (some willows are quite tolerant of 2,4-D) and cottonwoods are generally found in pure stand often enough so that D alone may sometimes be used on them.

The other more common species of woody plants of this area may be considered as more or less susceptible to brush killer mixtures or 2,4,5-T. If the dominant brush is mostly of resistant species, it is probable that 2,4,5-T alone will be more economical than brush killers.

Even though the trunks or stems are readily killed, certain species have extensive root systems which are not killed by foliage sprays, or even by winter basal sprays. These roots send up numerous sprouts after treatment. These root-sprouting species can be controlled by frequent re-sprays, but will require this for eradication. Some common root-sprouting species are black locust, sumac, tree of heaven, sassafras, aspen, and poplar.

Herbicide Application

Herbicides can be applied in many ways. The more important are:

1. Foliage spraying.
2. Basal sprays—usually winter, but may also be used in summer.
3. Stump sprays.
4. Oil-water, "semi-basal" spray.
5. Various special methods—aerial spraying, application in cups or frills in tree trunks, to girdled trees, by soil injection, or by special tools.

Brush spraying today is perhaps 85 percent summer foliage spraying with high pressure ground equipment, the other 15 percent being stump, basal, airplane and other spraying, but the picture is changing rapidly.

Foliage Spraying

High volume foliage spraying, spraying all foliage and stems to thorough wetting, is versatile, economical, and can be used in most areas where brush control is a problem.

The most common and generally effective spray is 2,4-D plus 2,4,5-T, 50-50, in a low-volatile ester formulation at four pounds combined acid equivalent in 100 gallons of water. However, for many woody species it is the 2,4,5-T which is effective, and several important companies have gone to a program of 2,4,5-T only, also at 4 pounds per 100 gallons. When Ammate is used, the usual foliage spray formula is 0.6 to 0.8 pound of Ammate-X per gallon of water and 4 ounces of sticker-spreader per 100 gallons of spray.

Time of spraying. Foliage spraying may be done from the time the leaves are fully expanded in the spring until they start to turn color in the fall. In Ohio, this means that foliage spraying equipment, especially the large type sprayers, must stand idle about eight months each year. Even in this brief four-month period, spraying in the early part of the season is definitely more effective than late applications.

Equipment may vary from knapsack sprayers suitable only for very small basal or stump spraying to orchard-type power rigs, mounted on any truck suited to the terrain, with as much as 5,000 feet of hose and extra men and equipment. Piston-type pumps mounted on four-wheel drive trucks and orchard-type spray guns are standard equipment for right of way brush control.

Pressure should be set to give as little as feasible of fog or small droplets. Higher pressures may be used with larger discs in the spray gun since these produce less fog at high pressures than the smaller ones.

Thorough wetting of both leaves and stems is *essential* to foliage spraying, and many operators have adopted the procedure of spraying from the ground, carrying varying lengths of hose. This permits the spray man to operate in close proximity to the brush and accomplish such wetting or avoid spraying desirable plants. This practice is more common in utility right of way spraying than on roadsides where the brush is usually sprayed from a moving vehicle (Figure 1).

Amount of spray. The amount of spray used per acre determines to a considerable extent the thoroughness of coverage and the results. It will depend, of course, on the density and height of the brush, but with ordinary 3 to 6 foot brush on a right of way, at least 160 gallons of spray per acre must be used. From 225 to 250 gallons per acre is perhaps nearly average and should be figured as a requirement if a reasonably

Fig. 1—Spraying roadside from a moving spray truck. The nozzle by the man's right arm is used when it is necessary to spray further to the back of the right of way.

good job is desired. Up to 400 gallons per acre has been used with good results. The labor costs of spraying are so large that it does not pay to skimp in material and so have the job to do over sooner than necessary.

Height of brush to be sprayed. The height of brush is not, unless it is too small, a factor in the kill obtained by foliage spraying of woody plants. Where the operator can thoroughly cover, from top to bottom, all trees or brush of susceptible varieties, a high percentage of kill can be expected. The height of brush is a factor in:

1. Public relations. Large dead trees or brush are unsightly and lead to criticism.
2. Danger to adjacent susceptible plants or crops. Inevitably much more spray goes out over adjacent areas when spraying tall brush than low brush.
3. Obtaining proper coverage.
4. The cost of the operation. The cost in time and materials increases rapidly with the height.
5. Accessibility* or usefulness of the sprayed right of way for traffic, either foot or vehicular.

Generally it is not economical to spray dense stands of brush over

*See Fire Lanes, Page 31.

6 to 8 feet high. Along highways, since the public is involved, it is rarely desirable to spray brush more than 4 feet high.

Brush that is too tall or too dense should usually be cut. It may then be stump sprayed or be allowed to sprout and be foliage sprayed.

Regrowth. A higher percentage of regrowth usually follows foliage spraying than when other techniques are employed. Regrowth, depending mainly on the type of brush, often does not develop until the year after spraying. When plants are not completely killed by spraying, the sprouts which develop along the stem or from the root crown may be stunted and abnormal. This type of growth does not respond well to foliage spray, and it is often desirable to use basal sprays on such regrowth. Sprouts which develop from unsprayed stumps, when present in sufficient quantities, react in a normal manner and respond well to foliage spraying.

Adding oil to foliage sprays. The addition of 5 to 10 percent of oil above that in the D and T formulation as purchased has often been suggested. The value of this is in doubt. It tends to control evergreens, if they are a problem. For ordinary mixed woody plants it seems that such oil-water sprays may kill the leaves sooner and the roots less than the standard water carriers. If used, the D and T formulation should first be mixed with the oil, and then all added to the water.

Follow-up treatments. Regardless of the brush killing method, follow-up treatments are necessary. It is a fallacy to expect a 100 percent kill from a single spray application. The kill usually will vary from 65 to 95 percent, depending upon the species present, the care and experience of the operator, and the amount of spray applied.

The extent of follow-up spraying will depend upon:

1. Effectiveness of the first spray.
2. Degree of re-invasion from seedlings.
3. Degree of control required.

One, or sometimes two, foliage sprayings will bring most areas under control to the point where only new seedlings and hard-to-kill species need to be especially treated. Periodic maintenance sprays will prevent resprouts and new seedlings from gaining a foothold.

Summary, foliage spraying. The foliage sprays with 50-50 D and T brush killers, T alone, or silvex alone have been very much the basic spray program. However, their use is not always desirable. Some exceptions are:

1. Where prohibited by the property owner.
2. When the size, kind, and density of brush makes foliage spraying impracticable.
3. As a second or third spray when only resistant species remain.
4. When the area is inaccessible to equipment.

5. When vulnerable crops, gardens, or ornamental plants are nearby.
6. When public acceptance will be jeopardized.
7. Where it is desired to preserve the low shrub understory in spraying new rights of way.

Where these conditions exist, some alternatives are:

1. Use a different foliage spray matrial.
2. Apply basal spray.
3. Cut brush that cannot be sprayed and treat stumps or stubs from cut brush chemically.

Other Methods of Application

Basal spraying. Basal spraying consists of a thorough application of spray to the lower 18 inches or less of the trunks or stems and any exposed roots of uncut brush with no attempt to treat the tops. Sufficient spray must be used to permit free run-off to the root crown. The necessity for an excess of spray to run down the root crown to the roots cannot be over-emphasized. This works well on almost any size or kind of brush or trees. It is most effective on trees less than 6 to 8 inches in diameter.

The solution to be used in basal spraying usually consists of 12 to 16 pounds acid equivalent of a 50-50 D and T mixture, or T only, in 100 gallons of kerosene or diesel oil; that is, one gallon of a formulation containing 4 pounds acid equivalent mixed with 25 to 33-1/3 gallons of oil. It is important to use only an oil diluent. Sprays prepared with water only have not been successful.

Basal spraying, done properly, will give satisfactory results at any time of year, in either dormant or growing season. Summer basal spraying is particularly effective on root-suckering species (Page 12). Winter basal spraying is useful because it can be applied at less busy times of year and increases the length of the season that equipment and manpower may be used. Temporary equipment can be used, since there is no need for high pressure as in foliage spraying. An ordinary knapsack sprayer is capable of doing an excellent job. Done in the winter, basal spraying involves the least danger from drift to susceptible crops and shrubs; though drift to susceptible plants can cause injury, even in the dormant period. Brush basally treated in the winter may leaf out in the spring and die during the summer.

Stump spraying. This is the application of the basal spray solution to the cut surface (on large stumps, at the junction of wood and bark; sprouts never arise from the center of stumps), sides, root crown, and exposed roots of stumps. The stumps must be well soaked on all sides

and particularly at the root crown and down to the roots, as in basal spraying. Best results are obtained on stumps of 3 to 4 inches in diameter or larger. Smaller stumps and shrubs will also be killed, but under field conditions there are usually so many misses that results are unsatisfactory.

Although good results have been obtained where the treatment is delayed for some time, there are indications that application soon after cutting results in the killing of more of the tissue from which new shoots may arise. Small stumps and stubs are easier to see soon after cutting and a quick follow-up behind cutting and clearing operations is desirable.

Stumps can also be destroyed by distributing Ammate crystals on the cut surface (not on the bark, as what goes on the side of the stump will be wasted) or applying a strong solution (4 to 6 pounds of Ammate to each gallon of water) to them.

Basal or stump spraying is an effective and economical means of controlling brush when:

1. New right of way is cut through wooded areas.
2. Mopping-up hard-to-kill species after foliage spraying.
3. There is not enough brush to justify using large equipment.
4. Spraying in inaccessible places.
5. Spraying alongside or near susceptible crops.
6. It is desired to maintain the original cover of the forest floor.

(See page 26).

Oil-water semi-basal, or cane-foliage, spray. The treatment known as oil-water semi-basal, or cane-foliage, spray was developed by Dr. Bramble and associates in Pennsylvania to make it possible to apply a basal spray in the summer at a labor cost no higher than the summer foliage spray. The summer basal with an oil carrier only is applied so slowly that it requires nearly double the man-hours needed for a foliage spray. The semi-basal treatment is made with 3 gallons of a 4 pounds per gallon 50-50 D and T low-volatile ester formulation in an oil-water carrier, consisting of 10 gallons of No. 2 fuel oil plus water to make 100 gallons. The concentrate should be first mixed in the oil, then mixed with the water. **Only the lower two-thirds of the brush should be sprayed.** The top foliage should be living immediately after the spray. It has been definitely shown that spraying **all** of the tops with such a formula **reduces** the amount of root-kill. Apparently the oil helps to kill the leaves so quickly that little chemical is translocated to the roots from them.

Obviously, this spray requires greater care in application than ordinary foliage spraying, since it is often easier to spray the entire plant than only the lower part of it.

In Dr. Bramble's experiment in Pennsylvania, wherever enough volume was put on to insure a thorough treatment of the bases, including the roots and crowns, and to run down to the roots, without spraying all of the tops, this formula produced (by a slight margin) the most complete kill of all woody plants of any method of applying D and T. However, it has failed for other applicators under other conditions.

Spraying in frills, girdles, or cups. These techniques have been little used in Ohio, but are effective on practically all species. They are more certain than basal treatment on trees larger than 5 to 6 inches in diameter. Frills or cups are cut with an ax, as close to the ground as possible, and then treated with the basal spray solution of 2,4,5-T in oil or with dry Ammate. Girdling can be done with an ax or a special power-driven girdler. Girdles are made more effective by treating with D and T in oil. Undiluted 4 pounds per gallon amine formulation of 2,4-D, applied with a pump oil can, has given good results in frills or girdles in California.

Soil injection method. This recently developed method gives considerable promise of effectiveness and economy where good-sized trees are concerned. It consists of injecting a measured dose of herbicide (usually 2,4,5-T or monuron) alongside the roots of the tree. It is not adapted to small brush control.

Special tools have been devised, beginning with the Cornell tree-killing tool of a generation ago, to kill trees by injecting chemicals while making cuts in the bark. With present-day herbicides they are still experimental, but worth wider trial.

Aerial brush control. Aerial right of way spraying is practical in forest and in hilly, swampy, or otherwise inaccessible terrain where areas that may be damaged by drift are few or absent and ground spraying would be expensive or impossible. On jobs where aerial application is possible, up to 90 percent savings can be made; the airplane can treat 6 to 8 times as many acres per day as ground equipment.

In areas where appearance is unimportant, aerial spraying is an economical method of accomplishing side pruning or right of way widening. In forest management, entire acreages can be sprayed to kill or stunt unwanted deciduous trees and brush to allow desirable slower growing, overshaded evergreen species to develop.

Whenever this method of application is used, the applicator pilot is the key to the success of the project. He should be chosen very carefully.

Evaluation of Chemical Brush Control

The first effect of chemical brush control can be viewed as chemical cutting versus hand cutting. Initially it accomplishes the same thing—brush is stunted or killed to the ground, depending on the type of brush.

Economically, chemical brush control holds a big advantage, because where feasible—where dead brush is not objectionable to the public or of a size or density that will imperil the public or overhead lines, or will not interfere with inspection or maintenance operations—the same result is usually accomplished at an initial saving of from 40 to 60 percent.

A second major saving or benefit is control of regeneration. Regeneration after hand cutting is usually 90 percent or more, and sometimes, because of multiple sprouting, the brush problem becomes worse than it was originally (Figure 2). Where chemical control is used the percentage of regeneration is markedly reduced, often to a point of approximately a complete root kill. If regeneration is more than 60 percent, many would consider the operation a failure.

In addition, there are a number of minor benefits:

1. Regrowth from incompletely killed stumps or brush is stunted and much slower growing than from mechanical cutting.
2. Mop-up or repeated maintenance is cheaper and easier because the chemical spray kills poison ivy, briars, and grape vines.
3. Labor turn-over is smaller because most men prefer spraying to cutting brush.
4. Minor accidents such as cuts and bruises are reduced.
5. Lay-offs and claims from poison ivy and chiggers are reduced.
6. Power sprayers work continuously hour after hour without getting tired.
7. Fewer men accomplish more work.

Fig. 2—These six-foot sprouts are one year's growth after cutting. Spraying would have prevented this growth.

These benefits are often overlooked because a viewer is spurred to quick criticism by unsightly (though temporary) dead and dying brush. On long range programs where spraying is feasible, these benefits spell large savings over hand cutting costs.

Roadside Spraying

Under all ordinary conditions the ideal highway border is grass. Grass is low-growing, erosion defying, attractive in appearance, will permit and support occasional parking, and requires a minimum of maintenance. The D and T brush killers control a high proportion of the unsightly plants on the highway without injuring the grasses we wish to save. In addition they are economical, efficient, and permit flexible maintenance programs.

The Ohio highway program has demonstrated that sprayed roadsides need less mowing (handmowing is almost entirely eliminated) and present a neater appearance than those maintained by older, more expensive methods. Important savings have come because maintenance personnel are enabled to increase their area coverage without additional expense. Although costs of a season's spray program have risen in the past few years, mowing costs on sprayed areas have been considerably reduced. Mowing costs have been less each succeeding year after spraying and considerable over-all savings have been realized on roadside maintenance and repair of mowing equipment. Also, more labor time was made available for other projects.

Precautions in highway spraying. Herbicides, when misdirected or carelessly applied, can damage adjacent field crops, gardens, or ornamental home plantings, and lead to damage claims and severe public criticism. Safety is a primary consideration in planning any roadside spraying. The application of chemical brush killers should be carefully done by trained individuals. Hormone herbicides are an effective and useful tool, but they must be used carefully. Many complaints about highway spraying have arisen from damage to areas immediately adjacent to the roads; in too many cases sprays have been applied by careless untrained operators who did not know the potentialities of what they were using.

Anyone in charge of a spray truck, who sprays beside or near a field of tomatoes, tobacco, or grapes, ought to be discharged at once for not knowing enough about the material he is using to be trusted with its use. One contractor gives his spray crew foreman a percentage of the profits from the areas he treats and also requires him to pay half the damage claims up to $75 from sections he has sprayed—a plan which has kept this contractor's damage claims under $100 per

crew a year. Spraying can be done safely! Soybeans, alfalfa, and clover, while susceptible to the hormone herbicides and deserving special attention, need not be seriously affected by careful applications along the borders of the fields.

The Ohio highway spray program. The following recommendations are based upon successful herbicide control of weeds on Ohio's roadsides and are primarily for the control of weeds and low woody plants on highways that have been well maintained in the past by mowing.

1. Use a three-year program of three sprays per season. The long-chain low-volatile esters of 2,4-D and 2,4,5-T are usually the best formulations to use.
2. Apply the first spray early in the season. The proportion is 3 pounds acid equivalent 2,4-D in 100 gallons of water. Where woody plants are an important part of the growth to be controlled, 4 pounds acid equivalent of a D and T mixture should be used. In Ohio the starting time is later in the north than in the south; a rule of thumb is; "Don't start before poison ivy leaves are fairly well formed."
3. Make the second application of a spray containing 2 pounds of 2,4-D and 1 pound of 2,4,5-T in 100 gallons of water by July 1.
4. Make the third application before September 1, of a spray containing 3 pounds 2,4-D in 100 gallons of water.
5. After the three-year period, or perhaps earlier, only 1 or possibly 2 applications per year are needed, depending on the control obtained and the cover established.
6. Adequate equipment, trained crews, and accurate amounts of material must be used.
7. Before spraying, the areas should be surveyed, and desirable vegetation, brush-covered steep slopes subject to erosion, and areas too near to susceptible crops for safe spraying should be designated not to be sprayed.
8. Spraying and mowing operations should be coordinated and a program of fertilizing included.
9. If livestock claims arise, enlist the cooperation of the Department of Agriculture and especially the Reynoldsburg Diagnostic Service Laboratory of the Ohio Division of Animal Industry. (See Herbicide Poisoning, Page 26). All damage claims should be investigated at once, in order to have post-mortem reports on the animals by a competent veterinarian, if possible.

10. Claims for damage to crops and gardens should be investigated promptly and fairly, but should be allowed only when definitely justified. Paying unjustifiable claims merely leads to a rash of similar claims in the area the next year.

Spraying neglected roadsides. There are many hundreds of miles of secondary roads which, because of lack of funds, have not been maintained in the past and have grown up to heavy brush, sometimes almost closing the road. Here the recommendations for utility rights of way (Pages 23-26) may be followed.

When economy is the sole consideration, foliage spraying with brush killers once a year will destroy or stunt brush and prevent further encroachment on roadsides. The dead brush will be unsightly but, if there is no money to remove it, it will break down and rot away. By repeated treatment, even a heavy brush cover can be controlled.

On heavily traveled roads which have brush that is more than 4 feet high, the best procedure is to cut and dispose of it and apply a stump spray.

Advantages of herbicides in maintenance of highway rights of way. While economic advantages and enhancement of the roadside appearance are the principal dividends of spraying operations, there are other advantages which are more difficult to evaluate:

1. Fewer mowings each year, hence less hazard to workmen.
2. Reduction or eradication of poison ivy, ragweed, and other toxic and allergy-producing weeds.
3. Reduction of mosquito breeding places.
4. A definite contribution to driver safety, especially on curves, when control of brush improves sight lines.
5. Grass instead of brush on the roadside may reduce snow accumulations on the traveled way.
6. Elimination of weeds that may infest crop areas—an important contribution to farm weed control.
7. Elimination of cover that lures animals to roadside death trap areas.
8. Helps motorist to "give children a brake."

Chemical vegetation control is one of the most economical and effective tools for a roadside maintenance program. If carefully planned and skillfully carried out, a receptive and encouraging public will be met at every turn. If done carelessly, severe public criticism will be aroused.

Woody Plant Control On Utility Rights Of Way

Chemical brush control by utilities is complex and presents some different problems from other types of brush spraying. The electric utility industry, perhaps, has an especially critical problem. Electric current is essential to the health and economic well-being of nearly everyone; to provide continuous adequate service, a well-planned brush control program on right of way areas must be maintained at all times.

Brush control on controlled rights of way.
The main objectives of a good program are:

1. To keep aerial facilities free from service interruptions to customers caused by trees or brush.
2. To keep the right of way accessible throughout the year for maintenance and construction.
3. To reduce fire hazards.
4. To do these things at the lowest practical costs.
5. So far as is consistent with basic utility needs, to serve as many conservation interests of the public as possible; wildlife habitats, game refuges, aesthetic and recreational values.

Utility spraying on roadsides. Utility spraying along roadsides is quite similar in scope and problems encountered to the work done by highway crews, except that highway crews do not ordinarily spray beyond the limits of the berm, while utilities are interested in controlling brush beyond the highway limits because it may imperil continuous service to customers served by overhead wires erected along the edge of the highway limits.

"Utilities have been permitted and encouraged by legislative enactments and municipal ordinances over the years to make use of public highways for the location of their facilities—in order to make their services available to the greatest number of people at the lowest possible costs. Acquisition of private rights of way for utility facilities would have increased the cost of utility services without any corresponding decrease in cost of road construction. Highways are the arteries of modern civilization—they do not serve exclusively to accommodate vehicular travel, but they also serve as a means for providing other services which promote public welfare. In many areas it would be impossible to provide essential utility services to the public without use of public thoroughfares."*

*Austin L. Roberts, Jr acting general solicitor for the National Association of Railroad and Utilities Commissioners, in testimony before the Sub-committee on Roads of the House Committee on Public Works on July 8, 1953

Steps in a chemical program. On any type of land, the first step in converting from cutting to chemical control of brush is to develop a long range plan. It is not usual, but in some instances initial spraying costs may equal or exceed cutting costs. However, spraying leads to a long-term reduction in maintenance costs.

Chemical control is not a one-shot job; planning must include programs for future routine maintenance which permits treatment during both growing and dormant seasons.

The administrative part of the job consists of:

1. Preparing a complete long-range program.
2. Obtaining advance company budget approval.
3. Preparing specifications.
4. Letting out contracts.
5. Seeing that an adequate field force is on the job.
6. Consideration and trial of new techniques.
7. On-the-job visits and evaluation of results.

A pre-spray survey is the first step in planning the spray applications. The survey should include:

1. Location and marking of access roads, ditch crossings and fence openings.
2. Determination of species, density, approximate percentages, and acreages of the brush.
3. Determination of the availability of water and fuel oil supplies.
4. A check of crop conditions and location of herbicide-sensitive crops.
5. A check of rough terrain and hose pulling conditions.
    a. Steep grades across or in the direction of lines.
    b. Swamps, streams or other barriers to mechanical equipment.
    c. Plan hose layout in advance of the spray crew.
6. Determination of the width of right of way to be treated in various sections.

This advance planning will permit the spray crew foreman to concentrate on producing better quality work.

Except in a newly cut line, initial or conversion sprays are usually foliage sprays. In the interest of economy a spray crew must keep moving along; it cannot stop to search for small sprouts. If too little spray is used, even some of the easy-to-kill species may not be destroyed. If too many of them survive, a second spray is necessary.

If the remaining plants are a typical cross-section of the initial growth, a repeat foliage spray should probably be applied. However, if only certain species still survive generally, the method of application or material applied should be changed. Usually, when only hard-to-kill species remain, basal treatments are indicated. These hard-to-kill species

and other stunted but incompletely killed species may permit the lapse of several years without expenditure. A quick follow-up summer basal spray applied one year after application of either foliage or basal sprays has been very successful in eliminating hard-to-kill species such as oaks, ash and maple.

An Experiment in Right of Way Spraying

The Pennsylvania State University has published* progress reports of four years of continuous study of a state-controlled experiment on a utility right of way through full-canopied forest in an upland plateau using three different summer foliage sprays and summer and winter basal sprays. These are (except for C) essentially those generally used or recommended in Ohio. The report is summarized below.
The treatments were:

A. No spray.

B. Overall foliage spray of 2,4-D plus 2,4,5-T butoxy ethanol esters, half and half, at 4 pounds combined acid equivalent per 100 gallons of water.

C. Oil-water, semi-basal spray of 2,4-D plus 2,4,5-T at 6 pounds combined acid equivalent per 100 gallons spray in an oil-water carrier consisting of 10 gallons of No. 2 fuel oil and water to make 100 gallons.

D. General summer basal spray of 2,4-D plus 2,4,5-T at 12 pounds combined acid equivalent in 100 gallons of No. 2 fuel oil.

E. Selective winter basal spray of 2,4,5-T at 12 pounds acid equivalent in 100 gallons of No. 2 fuel oil.

F. Over-all foliage spray of Ammate at 3/4 pound per gallon of water; 4 ounces of DuPont sticker-spreader were added per 100 gallons of spray.

After two growing seasons, thorough and efficient application of each of the five spray techniques had given an adequate top kill of 94 percent and up of the total number of stems. In the sprouting of woody brush following top kill, the oil-water semi-basal and Ammate treatments resulted in the fewest number of sprouts per acre after 4 growing seasons, the foliage spray, the most.

Where a follow-up summer basal spray was applied 1 year after the original spray, the number of living woody stems per acre over 3 feet in height has been reduced to 2 or less on all treatments.

*Bramble, W. C, W. R. Byrnes and D. P. Worley. Effects of certain common brush control techniques and materials in game food and cover in a power line right of way Progress Report No. 4 Proceedings 11th Northeastern Weed Control Conference, pages 219-226 1957.

The ground layer in these plots was very different immediately after spraying. The selective basal sprays did not greatly modify the bracken-sedge-herb-blueberry cover present on the original forest floor and it has remained that since. The overall D and T foliage sprays eliminated everything except sedge and grass and the cover has remained dominantly that for 4 years. The overall Ammate spray eliminated nearly everything, and in the next year annual weeds (principally fireweed) up to 6 feet tall dominated the area. In the fourth year sedge had become dominant, but fireweed was still next in importance. The oil-water semi-basal summer spray was similar to Ammate, but did not eliminate bracken, and there was much less fireweed, lasting only one year. The ground cover is working back to the original in all plots, but the oil-water and broadcast plots are still a long way from it, after four years.

Improved game food conditions have resulted from all treatments because of the creation of a new cover type amidst the unbroken mixed oak plateau. Common game species of the region continued to use all treated areas during the third year after spraying—indicating that these areas are making an important contribution toward the maintenance of the game population.

There were no significant differences in distribution of the various wildlife species in the different treated or untreated areas, except that turkeys used only the Ammate plots. Deer, rabbits, and squirrels used all the areas. No sick or dead game animals have been seen in any plot since the treatments. Distribution of game seems to be more dependent upon topographic conditions and surrounding vegetation than the plant composition of the right of way, throughout 4 years of continuous study and observation.

This experiment emphasizes that chemical woody plant control can be planned to give whatever type of cover is most desired. These tests were planned to test the feasibility of producing a low shrub cover, which was produced by using selective basal sprays.

If grass cover had been desired, it could have been produced by seeding at once after the foliage spray or Ammate spray, followed by a clean-up basal spray. In Ohio, rights of way, other than those newly cut through forest, there is often enough grass present so that it will spread without seeding, though seeding is faster.

Herbicide Poisoning

Chemical brush control is so new that people in general are unfamiliar with the properties of the herbicides used. It is understandable, therefore, that any sickness or death of farm animals not readily explain-

able, which happens at or nearly at the same time that a utility or a highway department sprays across the pasture, should be blamed on the spray.

Since many hundreds of thousands of miles of roadside and right of way have been sprayed in the past 10 years, such cases have occurred and continue to occur, so that it is desirable to include a discussion of the problem here.

Experiments and experience in the toxicity of herbicides. Since the introduction of 2,4-D and other hormone sprays, many carefully conducted experiments as to their toxicity have been conducted. Various formulations of them have been put in the feed of animals, or sprayed on their pastures in such a way that they could eat nothing that had not been sprayed. In every one of these numerous carefully conducted tests, there were no symptoms of injury of any kind. Experiments with wildlife and game animals have given the same results. Determinations of the toxicity of 2,4-D by standard methods* indicate that a 1000 pound cow would have to eat one-half pound of 2,4-D at one time to be in danger. This is the amount usually applied to one-fourth acre of right of way. A cow would have to be a good consumer to eat that much sprayed material in one day!

The author has made experimental spray applications in University pastures many times since 1946. The University's purebred stock have never been removed; there has been no suggestion of difficulty. One of my colleagues ate one-half gram of 2,4-D daily for three weeks, and nothing happened!

Even more convincing is the fact that hundreds of thousands of acres of pasture have been sprayed with D and T herbicides in the last ten years to remove weeds and brush in the pasture, without injury to the stock in them. The burden of proof is emphatically upon anyone who, in the face of this immense amount of experiment and experience, asserts that 2,4-D or 2,4,5-T spraying is responsible for the sickness or death of animals.

Why, then, do the animals die? Over the years, deaths at first attributed to herbicide poisoning from 2,4-D and 2,4,5-T have been diagnosed as actually due to one of the following:

1. Malignant catarrhal fever in cattle.
2. Eperythrozoonosis in swine.
3. Internal parasites in sheep.
4. Anemia in horses.

*The technical determination is of what is known as the L.D. 50, that is, the dose that will kill approximately 50 percent of the animals of that species. The L. D. 50 for 2,4-D on cattle is given as 500 mg. per kilogram of body weight

5. Lead poisoning.
6. Poisonous plants.
7. "Hardware disease."
8. Arsenic.
9. Old age.
10. Accidental shooting and others.

There are, of course, deaths which coincide with spraying in which the actual cause cannot be determined. But unexplained deaths were occurring in pastures long before 2,4-D. A frequent experience of the author in that period was to receive a package of weeds from a farmer with a letter something like this—"My cow (or other animals) died in the pasture and the veterinarian doesn't know what caused it. He says it must be due to some poisonous plant in the pasture. Which of these plants is poisonous?" Usually none were; the deaths, then as now, were due to something the veterinarian could not diagnose.

The Reynoldsburg Diagnostic Service Laboratory of the Ohio Division of Animal Industry, Dr. Harry E. Goldstein, Veterinarian in Charge, has performed important services in diagnosing difficulties of livestock supposed to be poisoned by 2,4-D. The first four diagnoses listed above were made there. In any case where such poisoning is alleged, the animal should be gotten to the Laboratory for diagnosis as soon as possible. The Laboratory is also one of the many that have tested these products, and they report, "Research projects have definitely proven that 2,4-D and 2,4,5-T are non-toxic to livestock when used in the recommended concentration as herbicides."

Poisonous plants in the pasture. One possible connection between spraying and livestock poisoning is the fact that some plants, very shortly after being sprayed with 2,4-D, become more palatable and hence are eaten when they were not eaten before. A very few somewhat authenticated cases of poisoning, apparently from this cause, are on record. This however, is a hazard of poisonous plants in the pasture and not of herbicides. With livestock at today's values, poisonous plants have no place in a pasture.

One of the most common of poisonous woody plants is wild cherry, the leaves of which contain a glucoside which gives off hydrogen cyanide, or prussic acid, in breakdown. Wild cherry may be poisonous, **green or wilted**, if animals eat enough of it. We have no records of the hazard from wild cherry being increased by spraying, and definite experimental studies show that the cyanide content decreases steadily after spraying, to only 10 or 20 percent of that originally present within two weeks.

It should be pointed out that the symptoms of poisoning by plants are characteristic for each plant, and should usually be readily recognized.

A mere allegation of injury from some poisonous plant eaten after spraying is by no means proof of such a condition. A definitely poisonous plant should be present in the pasture, should show evidence of being consumed, and the symptoms of sickness and/or death should be those caused by that plant.

Six years ago there was some discussion of the effect of 2,4-D in increasing nitrate accumulation in certain plants to the point of causing poisoning. Members of the beet and amaranth families (sugar beets, lamb's quarters, rough pigweed, etc.) which are naturally nitrate accumulators, have been the plants involved. The matter is unproved as yet, but it is certainly a very rare cause of poisoning, if it ever occurs. It would be necessary for a 500 pound animal to eat 20 to 25 pounds green weight of these plants at one time to cause death. Furthermore, the symptoms of nitrate poisoning are very definite and clear-cut, and should be recognized by a competent veterinarian at once. If the animals are alive, they can be effectively treated. East of the Mississippi river, on generally low nitrogen soils, excessive nitrate accumulations are especially rare.

In summary:

1. Competent experimenters have, without exception, found 2,4-D, 2,4,5-T and related compounds and pastures and plants sprayed with them harmless to livestock of all kinds when used in herbicidal doses (or considerably heavier).
2. Thousands of acres of pasture have been sprayed to clean up weeds and brush without removing the stock, and without injury resulting.
3. There are two extremely remote eventualities in which 2,4-D spraying might result in poisoning, one of which involves the presence of poisonous weeds in the pasture before spraying, which should not be tolerated; the other is probably not found in this territory.
4. Insist on a diagnosis from a competent veterinarian, including a complete autopsy. This will dispose of most cases. In cases of alleged poisoning, the symptoms presented will be as varied as the causes of death in livestock.

Public Relations

The public relations aspects of chemical vegetation control, particularly for roadside and utility right of way spraying, are vital. Utilities and others must take every precaution to avoid errors: Carelessness can ruin the success of an entire program.

The public is increasingly aware that chemical vegetation control provides answers to many problems. However, there are many complaints and criticisms, justified and unjustified, which must be met by

those conducting spraying operations. Constructive criticism often leads to better work, workmanship, and understanding. All complaints should be promptly and courteously investigated. Poor work should be corrected and the responsible persons disciplined.

Any damaging of private plantings both in and out of the right of way constitutes poor work. Such work may arise from inadequate training of operators, lack of on-the-job supervision, improper equipment or spray material, equipment out of repair or adjustment, or various errors of judgment, but none of these things excuse them. Up to the present these may perhaps be considered as "growing pains" of a new technique, but with the knowledge and techniques now available such errors need not and should not be tolerated in the future.

A serious problem to those in this field is that of contractors who bid so low to get a job that they have to cut corners; then the safety and efficiency of their work is threatened. Contracts should always provide for competent supervision and immediate cancellation in the event of careless work.

"Those terrible-looking strips." The first spray application on areas previously neglected, or cut and allowed to sprout, is different from maintenance spraying because unsightly dead and dying brush and weeds are often left standing. This is unfortunate but is an economical means to a desirable end—a clear grass-edged highway or right of way with low growth only. A similar untidy situation occurs during the building of a new home; under construction a new home is littered, unsafe, and far from attractive, but we know that the situation is temporary and that beauty will follow. When the competing brush is removed, grasses can be established and fill the space formerly occupied by weeds and brush. True, while the brush is dying the appearance of these areas is undesirable, but the end result is so satisfactory that most people feel the temporary poor appearance is a small price to pay.

Certainly roadsides and rights of way covered with grass are much more attractive than those over-run with hap-hazard, unkept and perhaps toxic or allergy-producing plants of all descriptions.

In addition to appearance, three other considerations are of major importance; water resources, forestry conservation practices, and wildlife management.

Erosion and water run-off. Insofar as erosion and run-off after rains are concerned, there is little difference between grassy and brushy slopes. The least run-off occurs on natural forest lands, if there is ample mulch from leaf litter and trash. This is not formed on rights of way, so grassy rights of way are at least as desirable as brushy ones for the control of erosion.

Fire lanes. Easily traversed rights of way through forested lands have considerable merit as fire lanes.

The forestry division of the Ohio Department of Natural Resources does not cut and maintain wide fire lanes as such through forested areas because of the expense involved. Their approach to the problem is to keep constant lookouts at key spots and to maintain driveable roads through certain areas. Such roads permit easy access to construct fire lanes as the need arises. In the Department's opinion, a grassy right of way such as a utility might maintain, although it might be a greater fire hazard than a brushy one during a dry spell in July or August, is more desirable than a brushy one because of the accessibility it provides. A right of way grown up to dense brush, together with its tangle of grapevines, briars and poison ivy, can be less passable and a greater fire hazard than the surrounding woods.

Wildlife management. Game propagation and management and rights of way through forested lands present complex problems, and no definite rules can apply to all situations.

Large continuous stands of anything—grass, brush or full-canopied forests—are not good game producing areas. Only a few owls inhabit large continuous stands of dense pine; a full canopied forest with only dead brush and limbs at ground level is not desirable for game management purposes.

Experience has indicated, as a provisional rule-of-thumb, that 20 percent of brush is desirable in forested lands for game management purposes, but the proper distribution of that 20 percent is debatable. Proper distribution is dependent upon local topography and other ecological factors.

Compared to a square mile of forest, which is 640 acres, a 100 foot right of way one mile long (approx. 12 acres) contains a relatively insignificant amount of either brush or grass. There is another consideration—edges—which is more important. Twelve acres of grass right of way through a forested area is most desirable for game management because along this grassy strip are two miles of edges, a grass-to-forest edge along each side of the strip. Such a strip through a forest soon has two miles of strip brush along its edges thereby providing another set of edges—two miles of grass-to-brush and two miles of brush-to-forest — four miles of edges graduated from forest, through brush to grass and back up again, an ideal situation for wildlife. The question is the relative proportion of each of the areas. This is the best resolved to fit local conditions.

Chemical maintenance of rights of way is not unfavorable to game preservation or management.